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[Intervention Review]

Laryngeal mask airway versus bag-mask ventilation or endotracheal intubation for neonatal resuscitation

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ABSTRACT

Background

Providing effective positive pressure ventilation is considered to be the single most important component of successful neonatal resuscitation. Ventilation is frequently initiated manually with bag and face mask (BMV) followed by endotracheal intubation if respiratory depression continues. These techniques may be difficult to perform successfully resulting in prolonged resuscitation or neonatal asphyxia. The laryngeal mask airway (LMA) may achieve initial ventilation and successful resuscitation faster than a bag-mask device or endotracheal intubation.

Objectives

Among newborns requiring positive pressure ventilation for cardio-pulmonary resuscitation, is LMA more effective than BMV or endotracheal intubation for successful resuscitation? When BMV is either insufficient or ineffective, is effective positive pressure ventilation and successful resuscitation achieved faster with the LMA compared to endotracheal intubation?

Search methods

We used the standard search strategy of Cochrane Neonatal to search the Cochrane Central Register of Controlled Trials (CENTRAL 2017, Issue 1), MEDLINE via PubMed (1966 to 15 February 2017), Embase (1980 to 15 February 2017), and CINAHL (1982 to 15 February 2017). We also searched clinical trials registers, conference proceedings, and the reference lists of retrieved articles for randomised controlled trials and quasi-randomised trials.

Selection criteria

We included randomised and quasi-randomised controlled trials that compared LMA for neonatal resuscitation with either BMV or endotracheal intubation and reported on any outcomes related to neonatal resuscitation specified in this review.

Data collection and analysis

Two review authors independently evaluated studies for risk of bias assessments, and extracted data using Cochrane Neonatal criteria. Categorical treatment effects were described as relative risks and continuous treatment effects were described as the mean difference, with 95% confidence intervals (95% CI) of estimates.

Main results

We included seven trials that involved a total of 794 infants. Five studies compared LMA with BMV and three studies compared LMA with endotracheal intubation. We added six new studies for this update (754 infants).

LMA was associated with less need for endotracheal intubation than BMV (typical risk ratio (RR) 0.24, 95% CI 0.12 to 0.47 and typical risk difference (RD) -0.14, 95% CI -0.14 to -0.06; 5 studies, 661 infants; moderate-quality evidence) and shorter ventilation time (mean difference (MD) -18.90 seconds, 95% CI -24.35 to -13.44; 4 studies, 610 infants). Babies resuscitated with LMA were less likely to require admission to neonatal intensive care unit (NICU) (typical RR 0.60, 95% CI 0.40 to 0.90 and typical RD -0.18, 95% CI -0.31 to -0.04; 2 studies,191 infants; moderate-quality evidence). There was no difference in deaths or hypoxic ischaemic encephalopathy (HIE) events.

Compared to endotracheal intubation, there were no clinically significant differences in insertion time or failure to correctly insert the device (typical RR 0.95, 95% CI 0.17 to 5.42; 3 studies, 158 infants; very low-quality evidence). There was no difference in deaths or HIE events.

Authors' conclusions

LMA can achieve effective ventilation during neonatal resuscitation in a time frame consistent with current neonatal resuscitation guidelines. Compared to BMV, LMA is more effective in terms of shorter resuscitation and ventilation times, and less need for endotracheal intubation (low- to moderate-quality evidence). However, in trials comparing LMA with BMV, over 80% of infants in both trial arms responded to the allocated intervention. In studies that allowed LMA rescue of infants failing with BMV, it was possible to avoid intubation in the majority. It is important that the clinical community resorts to the use of LMA more proactively to provide effective ventilation when newborn is not responding to BMV before attempting intubation or initiating chest compressions.

LMA was found to offer comparable efficacy to endotracheal intubation (very low- to low-quality evidence). It therefore offers an alternate airway device when attempts at inserting endotracheal intubation are unsuccessful during resuscitation.

Most studies enrolled infants with birth weight over 1500 g or 34 or more weeks' gestation. As such, there is lack of evidence to support LMA use in more premature infants.

PLAIN LANGUAGE SUMMARY

Laryngeal mask airway versus bag-mask ventilation or endotracheal intubation for neonatal resuscitation

Review questions

Among all newborns requiring positive pressure ventilation for cardiopulmonary resuscitation, is effective positive pressure ventilation and successful resuscitation achieved faster with the laryngeal mask airway (LMA) compared to bag-mask ventilation (BMV)?

When BMV is either insufficient or ineffective, is effective positive pressure ventilation and successful resuscitation achieved faster with LMA compared to endotracheal intubation?

Background

Most newborns are vigorous at birth, but a small number need to be helped with breathing (assisted ventilation) in the delivery room. Infants who do not have effective breathing soon after birth can become severely depressed. Providing rapid effective ventilation in the delivery room is very important. Ventilation is often started using a manually-pumped oxygen bag to force air into a close-fitting face mask held over the infant's nose and mouth. If breathing remains depressed after using the manual resuscitation bag, a tube is placed directly into the infant's large airway (endotracheal intubation). Bag and mask ventilation and endotracheal intubation may not be possible when infants have airway obstructions or head and face abnormalities that obstruct the normal flow of air into their lungs and/or obstructing the view of the airway by the medical personnel attempting intubation. The LMA is an alternative to bag and mask ventilation and endotracheal intubation. LMA is a small mask attached to a silicone tube fitted into the throat to provide positive pressure ventilation into the airway.

Study characteristics

We included seven trials that recruited a total of 794 infants. Our updated search (February 2017) lead to inclusion of six new studies (754 infants). Five studies compared LMA with BMV and three studies compared LMA with endotracheal intubation to provide effective positive pressure ventilation for newborns requiring heart/lung resuscitation.

Key results

LMA can achieve effective ventilation during neonatal resuscitation in a time frame consistent with current guidelines and could be more effective than BMV in resuscitation settings.

Quality of evidence

Evidence quality ranged from very low- to moderate-quality.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. LMA compared to BMV for neonatal resuscitation

LMA compared to BMV for neonatal resuscitation

Patient or population: neonatal resuscitation
Setting:
Intervention: LMA
Comparison: BMV

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with BMV	Risk with LMA				
Failure with primary modality of resuscitation	Study population		RR 0.16 (0.09 to 0.30)	660 (5 RCTs)	⊕⊕⊕⊖ MODERATE [1]	
	194 per 1000	31 per 1000 (17 to 58)				
Need for intubation	Study population		RR 0.24 (0.12 to 0.47)	660 (5 RCTs)	⊕⊕⊕⊖ MODERATE [1]	
	158 per 1000	38 per 1000 (19 to 74)				
Apgar score ≤ 7 at 5 minutes	Study population		RR 0.34 (0.16 to 0.74)	511 (2 RCTs)	⊕⊕⊕⊖ MODERATE[2]	
	94 per 1000	32 per 1000 (15 to 69)				
Admission to NICU	Study population		RR 0.6 (0.4 to 0.9)	191 (2 RCTs)	⊕⊕⊕⊖ MODERATE[3]	
	438 per 1000	263 per 1000 (175 to 394)				
Death or HIE	Study population		RR 0.65 (0.17 to 2.43)	191 (2 RCTs)	⊕⊕⊖⊖ LOW[3 4]	
	52 per 1000	34 per 1000 (9 to 127)				

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

Apgar: A=Activity, P=Pulse, G=Grimace, A=Appearance, R= Respiration; **BMV**: Bag mask Ventilation; **HIE**: Hypoxic Ischemic Encephalopathy; **LMA**: laryngeal mask airway; **NICU**: Neonatal Intensive Care Unit; **RCT**: Randomised controlled Trial; **CI:** confidence interval; **RR:** risk ratio; **OR:** odds ratio;

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

[1]Downgraded one level for serious study limitations (The largest of the included studies was a quasi-randomised trial)
[2] Downgraded one level for serious study limitations (One of the 2 studies was a quasi-randomised trial)
[3] Downgraded two levels due to high risk of performance bias and detection bias in both studies
[4] Downgraded two levels due to moderate degree of heterogeneity (I^2= 46%)

Summary of findings 2. LMA compared to endotracheal intubation for neonatal resuscitation

LMA compared to endotracheal intubation for neonatal resuscitation

Patient or population: neonatal resuscitation
Setting:
Intervention: LMA
Comparison: endotracheal intubation

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with endotracheal intubation	Risk with LMA				
Failure to correctly insert the device	Study population		RR 0.95 (0.17 to 5.42)	158 (3 RCTs)	⊕⊖⊖⊖ VERY LOW[1]	
	26 per 1000	25 per 1000 (4 to 141)				
Successful insertion of device at first attempt	Study population		RR 1.01 (0.89 to 1.14)	108 (2 RCTs)	⊕⊖⊖⊖ VERY LOW[2]	
	904 per 1000	913 per 1000 (804 to 1000)				
Apgar score ≤ 7 at 5 minutes	Study population		RR 0.70 (0.34 to 1.45)	108 (2 RCTs)	⊕⊕⊖⊖ LOW[3]	
	250 per 1000	175 per 1000				

		(85 to 363)			
Soft tissue trauma after device inserted	Study population		RR 2.00 (0.58 to 6.91)	40 (1 RCT)	⊕⊕⊝⊝ LOW[4]
	150 per 1000	300 per 1000 (87 to 1000)			
Death or HIE	Study population		RR 0.59 (0.11 to 3.32)	68 (1 RCT)	⊕⊕⊝⊝ LOW[5]
	94 per 1000	55 per 1000 (10 to 311)			

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the __relative effect__ of the intervention (and its 95% CI).

Apgar: A=Activity, P=Pulse, G=Grimace, A=Appearance, R= Respiration; **ETT**: Endotracheal Tube;

LMA: Laryngeal Mask Airway; **RCT**: Randomised controlled Trial; **CI:** Confidence interval; **RR:** Risk ratio; **OR:** Odds ratio;

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

[1] Downgraded three levels due to very wide Confidence interval, unclear risk of selection bias and serious study limitations (one of the study was a quasi-random study)
[2] Downgraded three levels due to unclear risk for selection bias and serious study limitations (one of the study was a quasi-random study)
[3]Downgraded two levels due to unclear risk for selection bias and serious study limitations (one of the study was a quasi-random study)
[4]Downgraded two levels due to very wide Confidence interval and unclear risk of selection bias
Downgraded two levels due to very wide Confidence interval and serious study limitations (one of the study was a quasi-random study)
[5]Downgraded two levels due to serious study limitations as it was a quasi-random study with high risk of selection, performance and detection bias

BACKGROUND

Description of the condition

While most newborns are vigorous at birth, 1% to 13% will require assisted ventilation in the delivery room (Finer 1999; Kattwinkel 1999; Kattwinkel 2010; Niermeyer 2000; Trevisanuto 2004a; Trevisanuto 2004b; Wyckoff 2000; Zanardo 2004). Ineffective ventilatory support is the most common clinical event contributing to severe neonatal depression and the need for intensive resuscitation in the delivery room (Perlman 1995). Providing rapid and effective positive pressure ventilation is considered to be the most important component of successful neonatal resuscitation (Niermeyer 2000; Weiner 2016).

During cardiopulmonary resuscitation, ventilation is frequently initiated with a manual resuscitation bag and face mask ventilation (BMV) followed by endotracheal intubation if neonatal depression continues. However, these techniques may be difficult to perform successfully. Effective BMV is a skill that must be learned and practiced. Incorrect mask placement allows air to leak around the mask. Excessive pressure to the mask may result in soft tissue damage to facial structures (Hagberg 2005). Laboratory investigations have suggested that commonly used BMV devices may deliver inconsistent tidal volumes, excessive peak pressures, and inadequate positive end-expiratory pressure (Finer 2001). Videotape recordings of neonatal resuscitations demonstrate that resuscitators were frequently unable to achieve adequate chest expansion using BMV (Carbine 2000).

Endotracheal intubation is attempted when adequate ventilation cannot be established. This procedure requires considerable training, experience, and skill. It has been reported that physicians completing paediatric training frequently fail to intubate the trachea despite multiple attempts (Falck 2003). Even experienced resuscitators may at times require prolonged attempts to successfully intubate the neonatal trachea (Carbine 2000; Noblett 1995). Furthermore, providing BMV or endotracheal intubation may not be possible for infants with airway obstructions and craniofacial anomalies such as the Pierre Robin sequence. In these infants, additional airway adjuncts and advanced procedures may be required. The laryngeal mask airway (LMA) is a device that could provide an alternative to either BMV or endotracheal intubation for newborns requiring assisted ventilation in the delivery room (Trevisanuto 2004c).

Description of the intervention

LMA is a small mask with an inflatable cuff attached to a silicone airway tube. The LMA is inserted orally using the operator's index finger and guided along the hard palate without laryngoscopy or other instruments. When the device is fully inserted, the mask lumen sits over the laryngeal opening and the cuff conforms to the contours of the hypopharynx occluding the oesophagus with a low-pressure seal. After inflating the cuff, LMA ventilation can be used to control the airway of the spontaneously breathing person or to provide positive pressure ventilation. LMA is used for both adult and children's anaesthesia and is the initial adjunctive airway device recommended by the American Society of Anaesthesiologists' difficult airway algorithm (Apfelbaum 2013). LMA use has also been tested in preterm neonates in non-resuscitation settings for surfactant administration to avoid endotracheal intubation (Barbosa 2012; Barbosa 2017; Pinheiro 2016; Wanous 2017). In a review on supraglottic airway devices during neonatal resuscitation Schmolzer 2013 included four trials that compared positive pressure ventilation delivered by an LMA versus bag and mask or an endotracheal tube. Infants in the LMA group were intubated less frequently than infants in the bag and mask ventilation group; LMA group infants had fewer unsuccessful resuscitations. Schmolzer 2013 also included two small trials that enrolled preterm infants and compared surfactant administration via LMA versus via endotracheal tube (Pinheiro 2016; Roberts 2017).

How the intervention might work

Laryngeal mask airways (LMAs) have been shown to be effective for ventilating newborns weighing more than 2000 g or who were delivered at 34 weeks' gestation (Esmail 2002; Gandini 1999; Trevisanuto 2004a). The potential advantages of using LMA for neonatal resuscitation include the ease of insertion without laryngoscopy and minimal instrumentation of the larynx. Potential disadvantages include gastric distention, inadequate alveolar ventilation, and possible difficulty suctioning the airway or administering emergency endotracheal medications.

Why it is important to do this review

The 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care regarding Neonatal resuscitation states that a laryngeal mask is recommended during resuscitation of term and preterm newborns at 34 weeks or more gestation when tracheal intubation is unsuccessful or is not feasible (Wyckoff 2015). However, they did not recommend routine use of LMA either as a primary airway device (as an alternative to BMV) or as a secondary airway device (as alternative to endotracheal intubation). Moreover, LMA has not been evaluated for infants with meconium-stained fluid, during chest compressions, or for administration of emergency endotracheal medications.

Given that establishing ventilation is the most critical aspect of successful neonatal resuscitation, it is important to answer two questions: does LMA achieve initial ventilation and successful resuscitation faster than BMV, and when BMV is either insufficient or ineffective, does LMA achieve effective ventilation and successful resuscitation faster than endotracheal intubation?

OBJECTIVES

Primary objectives: (1) Among all newborns requiring positive pressure ventilation for cardiopulmonary resuscitation, is effective positive pressure ventilation and successful resuscitation achieved faster with the LMA compared to BMV? (2) When BMV is either insufficient or ineffective, is effective positive pressure ventilation and successful resuscitation achieved faster with the LMA compared to endotracheal intubation?

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised and quasi-randomised controlled trials. Studies describing laryngeal mask airway (LMA) placement in the operating room for airway control during anaesthesia, studies using LMA for surfactant delivery and those describing use of LMA for airway control during diagnostic bronchoscopy were excluded.

Types of participants

1. Term or preterm infants who required positive pressure ventilation for cardiopulmonary resuscitation due to any cause during the first 28 days of life.

Types of interventions

1. LMA used for initiating positive pressure ventilation during neonatal resuscitation, compared to bag and face mask manual ventilation (BMV).
2. LMA used as a secondary airway device during neonatal resuscitation, when BMV was found to be insufficient or ineffective, compared to endotracheal intubation.

Types of outcome measures

Primary outcomes

1. Need for endotracheal intubation (LMA versus BMV studies only).
2. Failure with primary modality of resuscitation (LMA versus BMV studies only)
3. Ventilation time (time from birth, or from the beginning of intervention, until the discontinuation of positive pressure ventilation as part of resuscitation).
4. Time to spontaneous breathing or described as time to definitive response following the onset of intervention. (LMA vs. BMV studies only)
5. Admission to NICU.
6. Failure to correctly insert the device (LMA versus endotracheal intubation studies only).
7. Successful insertion of device at first attempt (LMA versus endotracheal intubation studies only).
8. Time to complete procedure, defined as time required to correctly insert the device from the onset of intervention (LMA versus endotracheal intubation studies only).
9. Death or hypoxic ischaemic encephalopathy (HIE) in the delivery room.

Secondary outcomes

1. Time until heart rate achieves greater than 100 beats per minute.
2. Time from birth, or from beginning of intervention, to pink skin colour(LMA versus endotracheal intubation studies only).
3. Apgar score less than or equal to 7 at 5 minutes.
4. Apgar score at 5 and 10 minutes.
5. Need for epinephrine administration.
6. Frequency of soft tissue trauma with the use of the device (LMA versus endotracheal intubation studies only).

Search methods for identification of studies

Electronic searches

We used the criteria and standard methods of Cochrane and Cochrane Neonatal to conduct searches (see the Cochrane Neonatal search strategy for specialized register).

We conducted a comprehensive search including: Cochrane Central Register of Controlled Trials (CENTRAL 2017, Issue 1) in the Cochrane Library; MEDLINE via PubMed (1966 to 15 February 2017); Embase (1980 to15 February 2017); and CINAHL (1982 to 15 February 2017). We used the following search terms: (laryngeal masks (MeSH) OR laryngeal mask* OR LMA) AND (resuscitation (MeSH) OR resuscitation) with database-specific limiters for RCTs and neonates (see Appendix 1 for database search strategies). We did not apply language restrictions.

We searched clinical trials registries for ongoing or recently completed trials (clinicaltrials.gov; the World Health Organization International Clinical Trials Registry Platform www.whoint/ictrp/search/en/, and the ISRCTN Registry).

Searching other resources

We searched for conference abstracts from Pediatric Academic Societies (PAS) and European Society for Paediatric Research (ESPR). Searches were carried out in Abstracts to View and Pediatric Research (2000 to 15 February 2017).

We also searched the reference lists of any articles selected for inclusion in this review to identify additional relevant articles.

Data collection and analysis

Selection of studies

Two review authors (MQ and MK) independently evaluated potentially relevant studies for inclusion.

Data extraction and management

Two review authors extracted data independently from the included trials using a standardised data extraction form. Study authors were contacted for clarifications if required. Data were entered into RevMan version 5.3 (Review Manager 2014) by one review author and checked for accuracy by a second review author. Discrepancies were resolved by discussion.

Assessment of risk of bias in included studies

Two review authors (MQ and MK) independently assessed the risk of bias (low, high, or unclear) of all included trials using the Cochrane 'Risk of bias' tool (Higgins 2011) for the following domains:

- Sequence generation (selection bias).
- Allocation concealment (selection bias).
- Blinding (performance bias and detection bias)
- Incomplete outcome data (attrition bias).
- Selective reporting (reporting bias).
- Any other bias.

Any disagreements were resolved by discussion and consensus. The Cochrane 'Risk of bias' tool is presented in Appendix 2.

Measures of treatment effect

We used risk ratio (RR) and risk differences (RDs) with 95% confidence intervals (CIs) to analyse discrete variables. We used weighted mean differences (WMD) with 95% CIs for pooling data from continuous variables. We used RevMan version 5.3 to conduct meta-analyses (Review Manager 2014).

Unit of analysis issues

We did not include cross-over trials to comply with recommendations that use of cross-over designs should be restricted to situations in which this is unlikely to carry-over treatment effects across periods (Elbourne 2002).

Dealing with missing data

We contacted primary trial authors to request missing data. We imputed standard deviation (SD) estimates for continuous outcomes where such data were missing, according to Cochrane *Handbook* guidance (Higgins 2011). We discussed the potential impact of missing data on review findings.

Assessment of heterogeneity

We assessed heterogeneity between included trials using the I^2 statistic (Higgins 2011). We graded the degree of heterogeneity as 0% to 25% for no heterogeneity, 25% to 49% for low degree of heterogeneity, 50% to 74% for moderate degree of heterogeneity and 75% to 100% for high degree of heterogeneity. We combined trial data using the fixed-effect model.

Assessment of reporting biases

We searched for any published version of trial protocols for the included studies. If available, the reported outcomes in a trial were compared with its protocol for any deviations.

Data synthesis

We performed statistical analyses using RevMan version 5.3 (RevMan 2014). Data were analysed using Cochrane Neonatal standard statistical methods. Categorical treatment effects were described as RR with 95% CIs. Numbers needed to treat for an additional beneficial outcome were calculated for outcomes that were statistically significant. Continuous treatment effects were described as the mean difference with 95% CIs. A fixed-effect model was assumed for meta-analyses to pool results from the included studies.

Quality of evidence

We used the GRADE approach, as outlined in the GRADE *Handbook* (Schünemann 2013), to assess the quality of evidence for the following clinically relevant outcomes:

Comparison 1: LMA versus BMV

- Failure with primary modality of resuscitation.
- Need for intubation.
- Apgar score ≤ 7 at 5 minutes.
- Admission to neonatal intensive care unit (NICU).
- Death or HIE.

Comparison 2: LMA versus endotracheal intubation

- Failure to correctly insert the device.
- Successful insertion of device at first attempt.
- Apgar score ≤ 7 at 5 minutes.
- Death or HIE.

Two review authors independently assessed the quality of the evidence for each outcome. We considered evidence from randomised controlled trials as high quality but downgraded the evidence one level for serious (or two levels for very serious) limitations based on: design (risk of bias), consistency across studies, directness of the evidence, precision of estimates and presence of publication bias. We used GRADEpro GDT to create a 'Summary of findings' table to report the quality of the evidence.

The GRADE approach results in an assessment of the quality of a body of evidence in one of four grades:

1. High: We are very confident that the true effect lies close to that of the estimate of the effect.
2. Moderate: We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
3. Low: Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
4. Very low: We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

Subgroup analysis and investigation of heterogeneity

We planned for subgroup analyses based on the following characteristics:

- Population characteristics: very low birth weight infants (< 1500 g), newborns with craniofacial anomalies.
- Type of resuscitator (nurse, respiratory therapist, physician, trainee).

However, we did not perform subgroup analyses because insufficient data were available for the specified subgroups.

Sensitivity analysis

We planned sensitivity analysis to explore methodological heterogeneity of the included studies. We classified studies at low risk of bias if they had adequate sequence generation and allocation concealment.

RESULTS

Description of studies

See Characteristics of included studies and Characteristics of excluded studies.

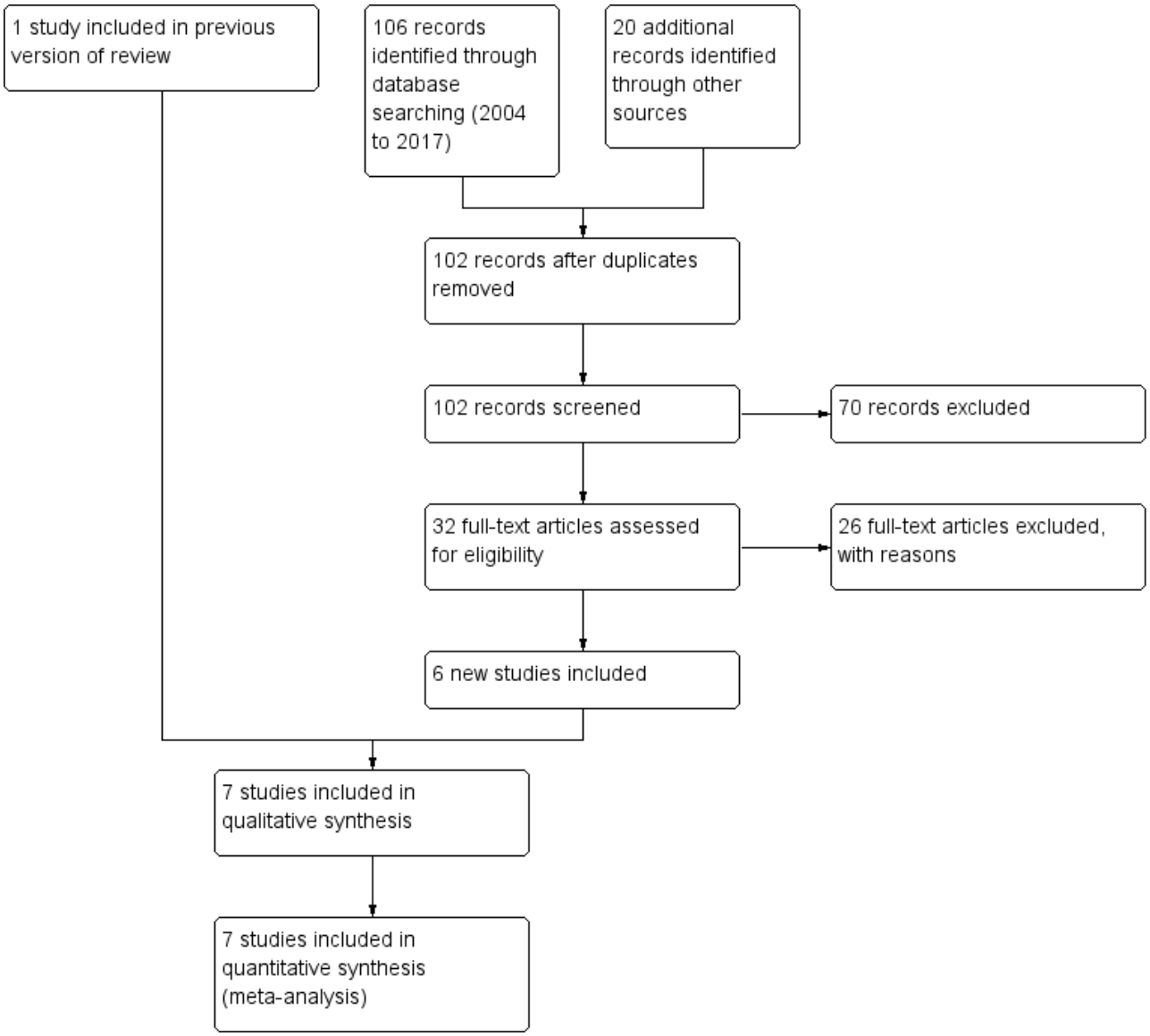
Results of the search

The electronic search strategy retrieved 1306 unique citations of which 1273 citations were excluded based upon the title and abstract screening.

Included studies

We included a total of seven randomised controlled trials that met the inclusion criteria (Figure 1). Five studies (661 infants) compared laryngeal mask airway (LMA) to bag and face mask manual ventilation (BMV) (Feroze 2008; Pejovic 2015; Singh 2005; Trevisanuto 2015; Zhu 2011); and three studies (158 infants) compared LMA with endotracheal intubation (Esmail 2002; Feroze 2008; Yang 2016).

Figure 1. Study flow diagram: LMA versus BMV or endotracheal intubation for neonatal resuscitation review update



Esmail 2002 compared LMA (size 1) as a secondary airway versus endotracheal intubation among 40 newborns requiring resuscitation in the delivery room at a single centre. Each treatment group had 20 neonates, who were similar with respect to birth weight and gestational age. The mean birthweight ± SD was 3369 ± 655 grams in the LMA group and 3450 ± 565 grams in the ETT group. The randomisation method was not described. The number of placement attempts made with each device, elapsed time, skin colour, heart rate, spontaneous respiratory rate, and Apgar score (1, 5, 10 minutes) were reported. The individual completing this assessment was not blinded to treatment allocation. Details of who made the outcome assessments were not provided. A fibreoptic laryngoscope was used to ascertain the position of the LMA and evaluate for soft tissue trauma. It was not clear whether the position of the endotracheal intubation and soft tissue trauma below the level of vocal cords were assessed. The timing of placement and trauma assessments were not reported. The resuscitators' level of training and professional credentials were not described.

Singh 2005 included 50 neonates born by caesarean section at over 35 weeks gestation, weighing over 1500 g, with apnoea for more 30 seconds or Apgar score less than 6 at 1 minute of age or heart rate less than 100 beats per minute after 30 seconds. Infants were assigned randomly to LMA (25 infants) or BMV (25 infants). A manual non-algorithmic method using identical paper slips with the study intervention placed in a bottle was used for randomisation Singh 2013 [pers comm]. The clinician was unaware of allocation until the need for intervention. Standard protocol for newborn resuscitation was followed in terms of drying, suctioning, positioning, providing warmth and free flow oxygen by mask at 5 L/min. If the infant was found depressed at 30 seconds, positive pressure ventilation was started according to the protocol of the group to which the infant had been randomised. All infants were resuscitated with 100% inspired oxygen. The study reported number of attempts and time required to achieve correct placement of LMA, ventilation success based on chest expansion and breath sounds heard bilaterally, pink up time, Apgar score at 1 and 5 minutes, total duration of positive pressure ventilation. The study also reported difficulties

and complications encountered, need for endotracheal intubation, and maximum inflation pressure required for adequate chest inflation. The resuscitators were all anaesthesiologists Singh 2013 [pers comm].

Feroze 2008 included 75 neonates born by elective or emergency caesarean section at a single centre, with birth weight over 1500 g and Apgar score less than 4, selected on the basis of non-probability convenience sampling. The randomisation method was not described. Infants were assigned to one of three arms (25 infants in each). Infants were ventilated with endotracheal intubation, BMV and LMA respectively. Resuscitation was performed by second year residents in anaesthesia who were conversant in neonate resuscitation techniques, and were supervised by a consultant anaesthetist. Where neonates could not be ventilated using endotracheal intubation and BMV, LMA was used. The efficiency of LMA ventilation for infants was evaluated in terms of ease of placement and ventilation. The time required for each technique to provide effective ventilation was reported. The adequacy of ventilation was gauged by the neonate's colour, pulse oximetry, Apgar score (1, 5, 10 minutes), chest movement and heart rate by auscultation.

Pejovic 2015 conducted a randomised clinical trial that involved 50 asphyxiated neonates with birth weight over 2 kg who were resuscitated by midwives using a specific LMA device (I-gel) (25 infants) or face mask ventilation (25 infants). A neonatologist or an anaesthesiologist supervised the resuscitation. The interventions were filmed and resuscitation data were collected from video review. Data collected included the total ventilation time, time for heart rate improvement, death or hypoxic ischaemic encephalopathy (HIE) in the delivery room or at 24 hours. Procedure-related adverse effects and need for admission to the neonatal intensive care unit (NICU) were reported.

The study by Trevisanuto 2015 involved 142 neonates at gestational age of 34 or more weeks, and expected birth weight of 1500 g or more needing positive pressure ventilation at birth. Infants were randomised to laryngeal mask airway ('Supreme Laryngeal Mask Airway = 71 infants) or face mask (71 infants). A total of 44 study participants (15 physicians and 29 nurses) were trained in the preparation and insertion of LMA (size 1). After initial steps (warming, clearing airway, drying, and stimulation), positive pressure ventilation with LMA or face mask with bag was initiated in infants with apnoea, gasping, or heart rate less than 100 beats per minute (or any combination). The primary outcome of this study was the success rate of the resuscitation devices (LMA or face mask). Resuscitation success was defined as achieving effective positive pressure ventilation (chest movements and increasing heart rate) preventing the need for endotracheal intubation. Secondary outcomes included Apgar score at five minutes, time to first breath (defined as the first respiratory effort), time to first cry (defined as the first audible cry spontaneously emitted by the infant), death or moderate to severe HIE within seven days of life, admission to the NICU or general nursery, and complications secondary to the procedure.

Yang 2016 involved 68 neonates with a gestational age of 34 or more weeks, or anticipated birth weight of 2 kg or more, with heart rate below 60 beats per minute, despite BMV for 30 seconds. Infants were assigned quasi-randomly (odd and even birth date) to the size 1 classic LMA arm (36 infants) or endotracheal intubation ventilation (32 infants). The primary outcome was to identify any differences in the feasibility, efficacy, and safety between LMA ventilation and endotracheal intubation during neonatal resuscitation. Data collected during resuscitation included Apgar scores at 1 and 5 minutes after birth, time required for device insertion, number of attempts required for successful device insertion, number of newborns successfully resuscitated, time required to achieve successful resuscitation, and the total ventilation time. Successful resuscitation was defined as the infant establishing spontaneous breathing, heart rate greater than 100 beats per minute, and good muscle tone. The number of infants who were assigned to the LMA group and required change to endotracheal intubation was reported. Blood gases and glucose levels were obtained from cord blood immediately after birth, and from peripheral arterial samples one hour after resuscitation.

The study by Zhu 2011 involved 369 neonates with gestational age of 34 or more weeks, expected birth weight over 2 kg who required positive pressure ventilation at birth. Infants were quasi-randomised to resuscitation by LMA (205 neonates) or bag-mask ventilation (164 neonates), according to date of birth; LMA was used on even dates, and the BMV on odd dates. Seven paediatricians with at least three years experience in neonatology carried out all resuscitations. All were trained in LMA insertion by a tutor who had been trained according to the American Heart Association 2005 neonatal resuscitation guidelines. The standard LMA insertion technique described by Brain 1983 was used. The LMA was held in place and connected to a self-inflating bag for positive pressure ventilation. All infants were resuscitated using 100% inspired oxygen. During resuscitation, positive pressure ventilation was administered at 40 to 60 breaths per minute with oxygen at a flow rate of 6 to 8 L/min. Intubation was performed if the heart rate did not rise or remained less than 60 breaths per minute after 30 seconds of positive pressure ventilation with LMA or BMV. If neonates with meconium-stained amniotic fluid were not vigorous at birth, tracheal suction for meconium was performed before initiating positive pressure ventilation. Data collected during resuscitation included: Apgar score at one and five minutes after birth; LMA insertion time, rate of successful insertion at the first attempt, and the number of attempts required to insert the LMA successfully; duration of resuscitation: response time (the time period from starting LMA resuscitation to achieving an effective response), ventilation time; adverse effects during resuscitation; arterial blood gases, lactic acid and blood sugar level before and after resuscitation in 20 infants from each group. Successful resuscitation with LMA or BMV was defined as preventing the need for tracheal intubation.

Excluded studies

We excluded 26 studies. Of these, 20 were not randomised or quasi-randomised trials. Most represented single case reports or case series (Baker 2004; Baraka 1995; Brimacombe 1995; Brimacombe 1999; Brimacombe 2004; Bucx 2003; Denny 1990; Fernandez-Jur 2002; Fraser 1999a; Fraser 1999b; Gandini 1999; Gandini 2003; Mawer 1995; Nagahama 1995; Paterson 1994; Trawöger 1999; Trevisanuto 2004a; Trevisanuto 2004b; Yao 2004; Zanardo 2004).

Five studies reported the use of LMA for surfactant administration (Attridge 2013; Barbosa 2012; Barbosa 2017; Pinheiro 2016; Wanous 2017).

See Characteristics of excluded studies.

Risk of bias in included studies

We assessed all included studies as being at risk of bias; see 'Risk of bias' summary Figure 2 and Figure 3.

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

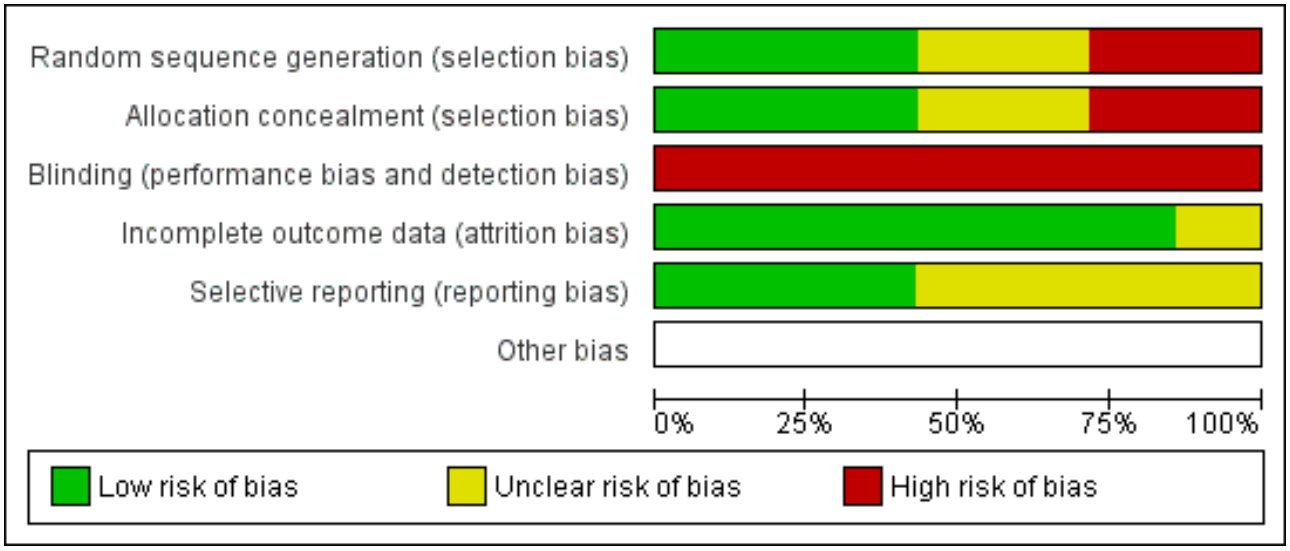
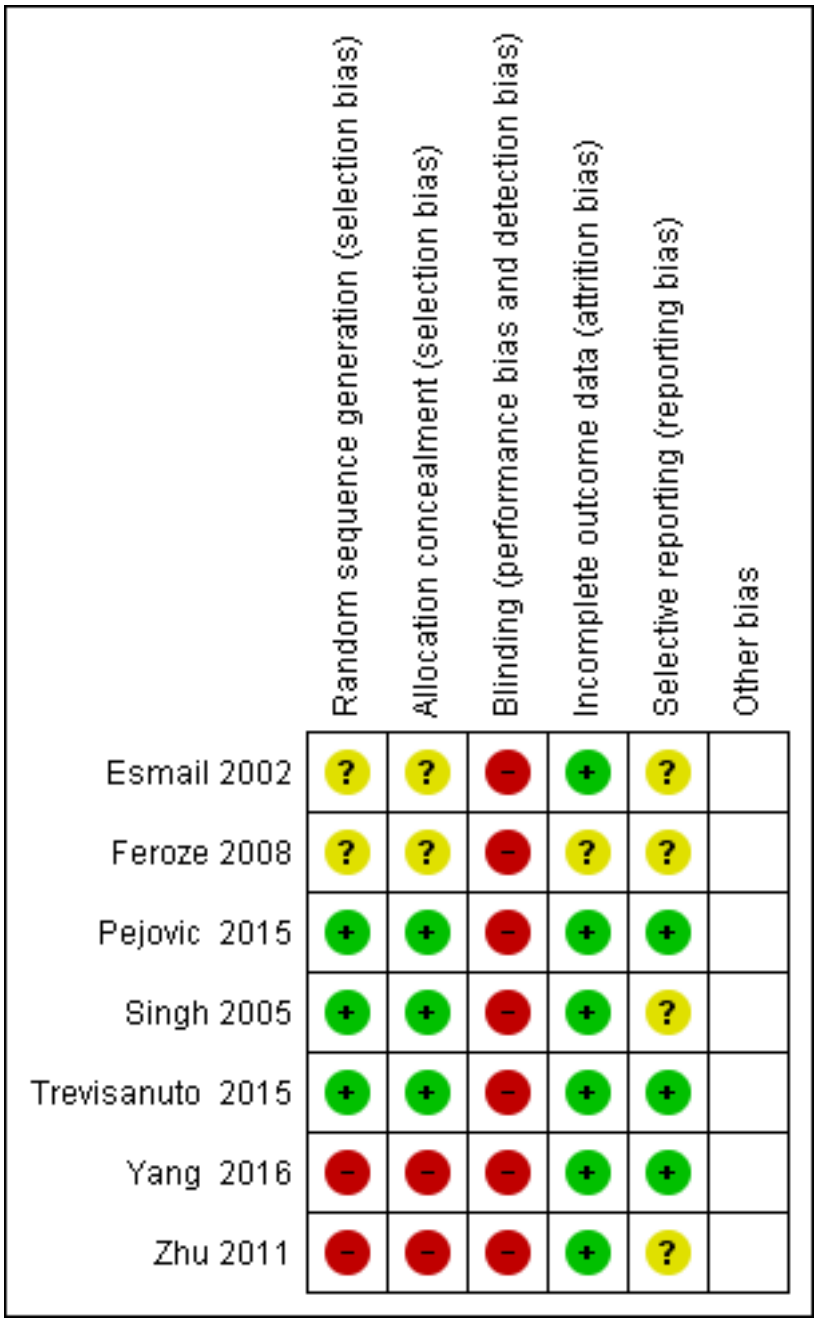


Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.



Random sequence generation (selection bias)

Singh 2005 used identical folded slips of paper on which the study intervention was noted and placed in a bottle (low risk of bias). Zhu 2011 and Yang 2016 allocated infants to intervention groups by odd or even dates (high risk of bias). Trevisanuto 2015 used computer-generated random sequencing (low risk of bias). Pejovic 2015 carried out randomisation by drawing a black or white toothpick from an opaque container at the time of resuscitation (low risk of bias). Randomisation method was not described in Esmail 2002 or Feroze 2008 (unclear risk of bias).

Allocation

The trialists were unaware of allocation until there was need for intervention in Singh 2005 (low risk of bias). Zhu 2011 and Yang 2016 could not conceal allocation to either intervention group because interventions were allocated according to odd and even dates (high risk of bias). Allocation was concealed by sequentially numbered sealed opaque envelopes in Trevisanuto 2015 (low risk of bias). Pejovic 2015 concealed allocation with the use of a small opaque container with two types of toothpicks which were drawn at the time of resuscitation (low risk of bias). Allocation concealment was not described for Esmail 2002 or Feroze 2008 (unclear risk of bias).

Blinding

Due to the nature of the interventions compared, there was no blinding attempted in any of the included trials (high risk of bias).

Incomplete outcome data

Outcome data were provided for all described infants in four studies (Esmail 2002; Pejovic 2015; Trevisanuto 2015; Yang 2016) (low risk of bias). Feroze 2008 did not report standard deviation or range estimates for successful resuscitation in endotracheal intubation and BMV groups which rendered meaningful comparisons challenging (unclear risk of bias). There were no missing data on reported outcomes but duration of follow-up was not explicitly stated in two trials (Singh 2005; Zhu 2011) (low risk of bias).

Selective reporting

It was unclear whether the authors of four trials (Esmail 2002; Feroze 2008; Singh 2005; Zhu 2011) reported trial data selectively; none of the included studies had protocols available online for reference (unclear risk of bias). Protocols were available for three trials (Pejovic 2015; Trevisanuto 2015; Yang 2016) (no risk of bias).

Other potential sources of bias

There were no other sources of potential bias identified.

Effects of interventions

See: **Summary of findings for the main comparison** LMA compared to BMV for neonatal resuscitation; **Summary of findings 2** LMA compared to endotracheal intubation for neonatal resuscitation

Comparison 1: Laryngeal mask airway (LMA) versus mask ventilation (BMV)

Five studies, which enrolled a total of 661 infants, compared LMA to BMV (Feroze 2008; Pejovic 2015; Singh 2005; Trevisanuto 2015; Zhu 2011). LMA was successfully inserted on the first attempt for most infants (Trevisanuto 2015: 65/71 infants; Zhu 2011 202/205 infants; Singh 2005 20/25 infants). Singh 2005 reported on one infant whose LMA was inserted with ease but an adequate chest expansion could not be observed, which required intubation. Singh 2005 also reported on an infant in the BMV group with cleft lip and palate who could not be successfully resuscitated with BMV and could not be intubated. This baby was eventually resuscitated with the help of LMA. Feroze 2008 mentioned that 1-2 attempts were required for insertion of LMA, whereas Pejovic 2015 did not report this outcome.

Primary outcomes

Need for endotracheal intubation

All five studies assessed for this outcome (Feroze 2008; Pejovic 2015; Singh 2005; Trevisanuto 2015; Zhu 2011). The need for endotracheal intubation was significantly lower in the LMA group than the BMV group (risk ratio 0.24, 95% CI 0.12 to 0.47; RD -0.10, 95% CI -0.14 to -0.06; 5 studies, 611 infants; I^2 = 34%). In Trevisanuto 2015, 6/71 infants in the LMA group (8.5%) needed intubation, but the number of intubations in the BMV group was not reported.

Failure with primary modality of resuscitation

All studies reported higher rates of failure with BMV (19% with BMV versus 3% with LMA; typical RR 0.16, 95% CI 0.09 to 0.30; I^2 = 43%), indicating LMA as the better modality for resuscitation.

Ventilation time (time from birth, or from the beginning of intervention, until the discontinuation of positive pressure ventilation as part of resuscitation) in seconds

Four studies (Pejovic 2015; Singh 2005; Trevisanuto 2015; Zhu 2011) reported this outcome with a mean difference of -18.90 seconds, (95% CI -24.35 to -13.44 seconds) favouring LMA. There was significant heterogeneity for this outcome (I^2 = 95%). This could be attributed to the Trevisanuto 2015 study where participants were ventilated for longer in LMA arm (median time: 60 versus 40 seconds), although median time to first breath was similar in both arms (50 seconds). Feroze 2008 did not report this outcome.

Time (seconds) to spontaneous breathing

Two studies (Trevisanuto 2015; Zhu 2011) reported this outcome with mean difference of -1.45 seconds (95% CI -2.98 to 0.08 seconds; I^2 = 0). Feroze 2008 reported that the time for effective resuscitation was one to two minutes in the LMA group compared to two to three minutes in the BMV group, but did not provide a statistical comparison. Singh 2005 reported pink-up times as 35.33 seconds in the LMA group, compared to 44.52 seconds in the BMV group. However, results from these studies could not be pooled for meta-analysis because neither Feroze 2008 nor Singh 2005 provided estimates for standard deviations or variance.

Admission to neonatal intensive care unit (NICU)

Two studies (Pejovic 2015; Trevisanuto 2015) reported this outcome (RR 0.60, 95% CI 0.40 to 0.90; I^2 = 0).

Death or hypoxic ischaemic encephalopathy (HIE) in the delivery room

Two studies (Pejovic 2015; Trevisanuto 2015) reported this outcome (RR 0.65, 95% CI 0.17 to 2.43; I^2 = 46%). Trevisanuto 2015 reported three deaths or HIE events in the delivery room for infants randomised to the LMA group and two infants in the BMV group. Pejovic 2015 reported that two infants in the BMV group experienced HIE events.

Death, all causes, before hospital discharge

Only Pejovic 2015 reported this outcome; there were no deaths at 24 hours of age.

Secondary outcomes

Time (seconds) until heart rate > 100 beats per minute

Pejovic 2015 reported that at 90 seconds heart rate was 151 ± 39 bpm in the LMA group and 126 ± 45 bpm in the BMV group (P = 0.07). None of the other studies reported on this outcome.

Apgar score ≤ 7 at 5 minutes

Two studies (Trevisanuto 2015; Zhu 2011) reported this outcome with typical relative risk of 0.34 (95% CI 0.16 to 0.74; I^2 = 0) favouring LMA. This outcome was not reported by the other included studies.

Apgar scores at 5 and 10 minutes

All studies except Pejovic 2015 reported Apgar scores at 5 minutes. Trevisanuto 2015 reported that the five minute Apgar score of >

7 was significantly higher in the LMA group infants (64/71 (91.4%) versus 50/71 (75.8%)) than the face mask group. Singh 2005 reported the range of five minute Apgar scores in LMA group was 6 to 10 compared to 7 to 10 in BMV group. Zhu 2011 reported that two neonates in LMA group and three neonates in BMV group had Apgar scores < 7 at five minutes. Feroze 2008 reported one infant in the LMA groups and three infants in the BMV group had Apgar scores < 4 at five minutes. Feroze 2008 provided data for 10 minute Apgar scores among infants as bar graphs, depicting similar results among the intervention groups.

Need for epinephrine administration

Trevisanuto 2015 reported that medications were administered to two infants in the LMA group and three in the BMV group (P = 0.99). No infants in other trials received epinephrine.

Frequency of post-resuscitation oral, airway, or facial trauma, or any other procedural related complication

No orofacial trauma was reported in six studies (Feroze 2008; Pejovic 2015; Singh 2005; Trevisanuto 2015; Zhu 2011). Singh 2005 reported that three LMA group infants developed gastric distension compared to seven infants in the BMV group. Zhu 2011 reported four vomiting and three regurgitation events in LMA group infants compared to two abdominal distention and one regurgitation events in the BMV group infants.

Comparison 2: Laryngeal mask airway (LMA) versus endotracheal intubation

Three studies, which enrolled a total of 158 infants, compared LMA with endotracheal intubation (Esmail 2002; Feroze 2008; Yang 2016).

Primary outcomes

Time required to correctly insert the device (insertion time)

All three studies reported on this outcome. However, only data from two studies (Esmail 2002; Yang 2016) could be pooled for meta-analysis with no difference noted (MD 0.31 seconds, 95% CI -0.27 to 0.88 seconds). Feroze 2008 reported similar insertion times for two interventions (9 ± 1.4 seconds for LMA versus 9.5 seconds for endotracheal intubation respectively). However, results could not be pooled for meta-analysis because SD estimates were not provided for the insertion time in endotracheal intubation group (Feroze 2008).

Failure to correctly insert the device

All three studies reported this outcome with very few failure events noted in either group (two failures in each intervention group). There was no difference in this outcome between intervention groups (RR 0.95, 95% CI 0.17 to 5.42).

Successful insertion of device at first attempt

Data from two studies (Esmail 2002; Yang 2016) reporting this outcome were pooled for meta-analysis, with no difference noted across the intervention groups (RR 1.01, 95% CI 0.89 to 1.14). Feroze 2008 did not provide data in a format that could be included for meta-analysis, however, it was mentioned that one to two attempts were required for insertion of LMA compared to two to three attempts for endotracheal intubation.

Ventilation time (time from birth, or from the beginning of intervention, until the discontinuation of positive pressure ventilation as part of resuscitation) in seconds

Both Feroze 2008 and Yang 2016 reported this outcome. Yang 2016 reported that ventilation time in the LMA group was slightly shorter than the endotracheal intubation group, but this was not significant. Feroze 2008 descriptively presented these data without providing a statistical comparison at between one and two minutes in the LMA group and 1.5 to 2.5 minutes in the endotracheal intubation group.

Death or hypoxic ischaemic encephalopathy (HIE)

Yang 2016 reported two HIE events in each intervention group. One infant in the endotracheal intubation group died.

Secondary outcomes

Time (seconds) until heart rate > 100 beats per minute

Esmail 2002 reported average heart rate ± SD for both groups at 10 second intervals (up to 90 seconds) on a graph. The average heart rate improved over the first 90 seconds in both groups. The study authors stated there was no statistically significant difference between the groups at any point.

Time from birth, or from beginning of intervention, to pink skin colour

Esmail 2002 graphically reported the number of subjects with uniform pink and uniform cyanotic skin colour at 10 second intervals (0 to 90 seconds). The skin colour improved over the first 90 seconds in both groups and the authors stated that there was no statistically significant difference between the groups at any point. In Feroze 2008 trial the pink up time was 35 to 40seconds for ETT, and 30 to 35 seconds for LMA. However, none of these studies provided standard deviation or variance estimates for statistical comparison. Yang 2016 did not report on this outcome.

Apgar score ≤ 7 at 5 minutes

Esmail 2002 and Yang 2016 reported this outcome. There was no difference noted between intervention groups (RR 0.70, 95% CI 0.34 to 1.45). Feroze 2008 did not report outcome data separately so was not included in the meta-analysis.

Apgar scores at 5 and 10 minutes

All three studies contributing data for this comparison reported Apgar scores at five minutes. Yang 2016 reported that six infants in LMA group and nine infants in the endotracheal intubation group had Apgar scores < 7. No infants in either group in Esmail 2002 had Apgar scores < 7. Feroze 2008 reported one infant each in the endotracheal intubation and LMA groups with Apgar scores < 4 at five minutes. Esmail 2002 and Feroze 2008 provided data for 10-minute Apgar scores as bar graphs which depicted similar results among the intervention groups.

Need for epinephrine administration

None of the studies reported this outcome.

Frequency of post-resuscitation oral, airway, or facial trauma, or any other procedural related complication

Esmail 2002 reported six infants with soft tissue trauma to epiglottis, uvula, and tongue in the LMA group compared to three infants in the endotracheal intubation group (RR 2.00, 95% CI 0.58 to 6.91). No orofacial trauma was reported in Feroze 2008. Trial

adverse events in the LMA group reported by Yang 2016 included vomiting (2 infants) and mild abdominal distention (1 infant). Adverse events in the endotracheal intubation group included laryngeal oedema (1 infant), tracheal bleeding (1 infant), and pneumothorax (2 infants).

DISCUSSION

The primary objectives of this review were to establish whether the laryngeal mask airway (LMA) can achieve effective ventilation faster than bag-mask ventilation (BMV) and whether it would be an effective alternative to endotracheal intubation when bag-mask ventilation fails.

Establishing effective positive pressure ventilation is the single most important aspect of successful neonatal resuscitation (Weiner 2016). It is, therefore, critically important to identify the most effective device for delivering positive pressure ventilation. BMV and endotracheal intubation are the most common traditional treatment options, but both have limitations including difficulties achieving effective and consistent tidal volumes, obtaining an effective seal, and using either device for newborns with craniofacial anomalies. A further challenge is the requirement for extensive training and practice.

We included seven randomised controlled trials that met the inclusion criteria. Five studies that enrolled a total of 661 infants compared LMA to BMV (Feroze 2008; Pejovic 2015; Singh 2005; Trevisanuto 2015; Zhu 2011). Three studies, enrolling 158 infants, compared LMA with endotracheal intubation (Esmail 2002; Feroze 2008; Yang 2016).

Results show that compared to the BMV, the use of LMA is more effective in terms of lower need for endotracheal intubation and shorter ventilation time. Infants initiated on BMV were more likely to fail the primary modality of providing positive pressure ventilation, although, some could be rescued by LMA, thus preventing endotracheal intubation. Compared to endotracheal intubation, the use of LMA was not associated with clinically significant differences in insertion time or failure to correctly place the device. Both techniques provided effective ventilation with no difference in the short-term clinical outcomes observed. However, most studies included infants with birth weights over 1500 g or 34 or more weeks gestation or both. Evidence relating to less mature infants is limited.

Theoretically, if LMA achieves effective ventilation faster than BMV, this technique may decrease numbers of newborns who would ultimately require chest compressions or resuscitation drugs. However, some questions remain unanswered, e.g., it would be important to establish whether the LMA can be used effectively during chest compressions . Also, LMA is technically a harder skill to learn as compared to BMV. Although, there was low failure rate in the included trials in terms of ability to initiate LMA in the participants, it is not clear whether same would be the case in real world settings given that LMA is technically a more challenging skill to learn compared to BMV.

We found higher than expected success rates associated with endotracheal intubation (Esmail 2002 100%; Feroze 2008 90%). This may have limited the investigators' ability to identify a difference between groups for successful placement of airway ventilation devices. In the literature, endotracheal intubation placement failure rates by residents and fellows has been reported to be much higher: Falck 2003 reported that only 50% to 62% of neonatal intubation procedures were successful on the first or second attempt by paediatric residents whereas 35% of the neonates could not be successfully intubated by a paediatric residents despite four attempts. Similarily, Bismilla 2010 reported the rate of successful intubation between 63% and 69% among paediatric residents and neonatal intensive care unit (NICU) fellows.

A sizable limitation of the review at study and outcome level is due to high risk of selection bias in the largest trial (Zhu 2011) and high risk of performance bias in all the studies. Additionally, at the review level, there was unclear risk of reporting bias in four of the seven trials, as their protocols were not available online for reference.

Despite the limitations of data, this review suggests that LMA is more effective than face mask ventilation and an effective alternative to endotracheal intubation for neonatal resuscitation. LMA insertion is now being routinely taught as a skill in neonatal resuscitation programs (Weiner 2016).

Summary of main results

We found that in term and near-term infants, LMA is more effective during resuscitation resulting in less need for endotracheal intubation and shorter ventilation time compared with BMV. Compared to endotracheal intubation, the use of LMA was not associated with clinically significant difference in insertion time or failure to correctly place the device.

Overall completeness and applicability of evidence

The validity and applicability of the results of this review are somewhat limited. Five included studies (Esmail 2002; Feroze 2008; Pejovic 2015; Singh 2005; Yang 2016) enrolled small numbers of participants. The largest analysis included 611 infants and revealed need for endotracheal intubation was significantly lower in the LMA group than the BMV group. However, the included studies provided insufficient data to inform comment on need for chest compression, epinephrine, and pulmonary complications such as pneumothorax and death.

Quality of the evidence

We included seven trials that met inclusion criteria. Of these, five studies that compared LMA with BMV, the quality of evidence was downgraded to low- to moderate because the largest of the included studies (Zhu 2011), which enrolled approximately 369 patients (55% of the total number of infants assessed), was at high risk of bias due to use of a quasi-randomised design with no allocation concealment. The other large trial in this category (Trevisanuto 2015) enrolled 142 patients and had moderate degree of heterogeneity . For the three studies that compared LMA with endotracheal intubation, (Esmail 2002, Feroze 2008,Yang 2016) quality of evidence was downgraded to low to very low as these studies enrolled a small number of infants, had a very wider confidence interval and included a quasi random study with high risk of performance and detection bias.

Potential biases in the review process

Modifications to primary and secondary outcomes in this updated review may have introduced bias into the review because we

applied these changes after the initial search and after review of outcomes reported by the included studies. Moreover, none of the trials included in this review was blinded due to the nature of the interventions. Many studies (Esmail 2002; Feroze 2008; Singh 2005; Zhu 2011) were considered at risk for selective reporting of results in the absence of availability of trial protocol. Zhu 2011 and Yang 2016 were quasi-randomised trials and lacked allocation concealment. Esmail 2002 and Feroze 2008 lacked important methodological details of method of randomisation and allocation concealment.

Agreements and disagreements with other studies or reviews

The findings of this review are consistent with the evidence from three observational studies. Paterson 1994 reported the first prospective series using LMA in place of BMV in the delivery room for term and near-term newborns. The study team resuscitated 21 newborns (weight range 2235 g to 4460 g) and successfully inserted the LMA at the first attempt in all 21 newborns. Gandini 1999 subsequently reported the a much larger delivery room series, which included 29 "low birth weight" newborns with six newborns < 1500 g. The LMA was inserted successfully during the first attempt in all 104 newborns and effective ventilation was achieved in 103 of 104 infants. Adequate chest expansion was achieved by 10 seconds (mean) in both normal and low birth weight newborns. Trevisanuto 2004a compared all newborns resuscitated using LMA in 2000 with a gestational age matched group resuscitated in the same year with BMV. The LMA was "easily inserted" and provided "effective ventilation" in 94/95 neonates during resuscitation. One infant who did not respond was ultimately intubated with an endotracheal intubation and was found to have a tension pneumothorax. In the gestational age-matched BMV comparison group, there were four newborns who did not respond to BMV and were successfully treated with LMA. Two of these newborns had micrognathia. In addition, there are several case reports in literature citing successful use of LMA as a life-saving rescue airway when both BMV and endotracheal intubation were unsuccessful in resuscitation of neonates (Baker 2004; Baraka 1995; Brimacombe 1995; Brimacombe 1999; Brimacombe 2004; Bucx 2003; Denny 1990; Fraser 1999a; Gandini 2003; Mawer 1995; Trawöger 1999).

AUTHORS' CONCLUSIONS

Implications for practice

Despite the limitations of the evidence discussed here, it is reasonable to conclude that in infants with birth weight over 1500 g and more than 34 weeks' gestation, laryngeal mask airway (LMA) is more effective during neonatal resuscitation compared to bag and face mask (BMV) for providing positive pressure ventilation. In studies that allowed LMA rescue of infants failing BMV, it was possible to avoid intubation in the majority. It is important that the clinical community resorts to the use of LMA more proactively to provide effective ventilation when a newborn is not responding to BMV before attempting intubation or initiating chest compressions. Further research could help to increase LMA use in practice for the subset of infants that were not included in the existing trials.

Implications for research

We found limited evidence of LMA use in very low birth weight newborns (< 1500 g). There was also insufficient evidence to evaluate LMA in the setting of meconium-stained amniotic fluid, chest compressions, or for the delivery of emergency intratracheal medications. Large, international, multi-centre, randomised controlled clinical trials, enrolling both term- and preterm infants, should aim to answer the following questions:

1. The efficacy of LMA devices in specific resuscitation settings, i.e. involving chest compressions, administering emergency intratracheal medications, and for meconium-stained amniotic fluid. Include comparison of strategies using of LMA as the primary mode of ventilation versus use when BMV is unsuccessful.
2. The efficacy of LMA devices in newborns with orofacial malformations (such as cleft lip and palate) which prevent effective ventilation with a face mask, and clinical conditions involving micrognathia or anterior airways providing difficulty with endotracheal intubation.
3. Whether LMA would be safer than endotracheal intubation in terms of adverse events associated with endotracheal intubation insertion (e.g. pneumothorax and vocal cord injury).
4. Whether LMA insertion in newborns is an easier skill to acquire compared to endotracheal intubation insertion.

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CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Esmail 2002

Methods	RCT. Single centre study (1999 to 2000).
Participants	**Inclusion criteria** • Newborns with expected gestation ≥ 35 weeks and expected birth weight ≥ 2.5 kg following cesarean section delivery. • Apgar score at one minute ranging from 0 to 3 (apnoea, heart rate < 100 bpm. • Need for positive pressure ventilation (PPV) using a bag-mask device). **Exclusion criteria** • Newborns with congenital anomalies. • Those requiring chest compressions. • Suspected diaphragmatic hernia. • Oropharyngeal pathologic lesions.
Interventions	**Group 1 (N = 20)** Ventilated with LMA (Size-1); PPV using a Jackson-Rees modification of an Ayres T-piece circuit with a pressure manometer to a maximum of 20 cmH_2O pressure. Allowed three LMA attempts, then cross-over to endotracheal intubation. **Group 2 (N = 20)** Ventilated with endotracheal intubation; two attempts within 40 seconds were allowed, then cross-over to LMA.
Outcomes	Time required to place device; time to PPV; skin colour, heart rate, spontaneous respiratory effort, breath sounds (measured at 10 second intervals starting a beginning of insertion attempt); Apgar score at 1, 5, 10 minutes; pulse oximetry (measured every minute until resuscitation completed); "response to resuscitation and airway patency" (15 to 30 second intervals); LMA position and soft tissue trauma (epiglottis, tongue, uvula) using a fibreoptic laryngoscope (not stated when this assessment took place).
Notes	Authors were not contacted during the preparation of this review. Source of funding not mentioned. A=Activity, P=Pulse, G=Grimace, A=appearance, R= Respiration BW=Birth weight LMA= Laryngeal mask airway
Risk of bias	
Bias	**Authors' judgement** **Support for judgement**

Esmail 2002 *(Continued)*

Random sequence generation (selection bias)	Unclear risk	Method of randomisation not described.
Allocation concealment (selection bias)	Unclear risk	Authors do not mention if allocation concealment was attempted.
Blinding (performance bias and detection bias) All outcomes	High risk	No blinding of interventions attempted.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcome data presented for all enrolled infants.
Selective reporting (reporting bias)	Unclear risk	No trial protocol available in public domain.

Feroze 2008

Methods	RCT. Single centre study; 75 infants born between 1 January 2002 to 31 May 2002.
Participants	**Inclusion criteria** • Birth weight > 1500 g. • Apgar score < 4/10 at onset. • Born via elective/emergency caesarean section with or without any maternal systemic disease. **Exclusion criteria** • Birth weight < 1500 g. • Neonates with birth trauma.
Interventions	Group A (N = 25): Ventilated with endotracheal intubation. Group B (N = 25): Ventilated with face mask. Group C (N=25): Ventilated with size 1 LMA.
Outcomes	Efficiency of LMA was evaluated in terms of ease of placement and ventilation, time required for each technique to provide effective ventilation, adequacy of ventilation as gauged by the colour of the neonate and pulse oximetry, chest auscultation, heart beat auscultation.
Notes	Contacted authors but no response received; Source of funding not mentioned A=Activity, P=Pulse, G=Grimace, A=Appearance, R= Respiration BW=Birth weight LMA= Laryngeal mask airway

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Method of randomisation not described.

Feroze 2008 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	Authors did not mention if allocation concealment was attempted.
Blinding (performance bias and detection bias) All outcomes	High risk	No blinding attempted.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Measures of dispersion not provided for several continuous outcomes reported.
Selective reporting (reporting bias)	Unclear risk	No trial protocol available in public domain.

Pejovic 2015

Methods	RCT to assess the efficiency and safety of I-gel™ uncuffed laryngeal mask airway (LMA) in neonatal resuscitation compared to face mask ventilation. Single centre study; 50 neonates randomised to resuscitation by midwives (one infant excluded post-randomisation for congenital cardiac malformation).
Participants	**Inclusion criteria** • Estimated gestation > 34 weeks. • Estimated weight > 2 kg. • Need for positive pressure ventilation (PPV) at birth. **Exclusion criteria** • Still birth. • Major malformations. • Severe prenatal depression (heart rate < 60 bpm 1 minute after birth).
Interventions	Group I (N = 25): Resuscitated with I-gel LMA. Group II (N = 25): Resuscitated with face mask.
Outcomes	**Primary outcomes** • Time to spontaneous breathing. • Ventilation time. • Time for heart rate to improve. **Secondary outcomes** • Proportion of infants who required advanced resuscitation (time frame: 1 day). • Proportion of infants with adverse birth outcome (time frame: 2 days) (death or hospitalisation) at 24 and 48 hours of life.
Notes	ClinicalTrials.gov: NCT02042118 (16 December 2013) Authors were contacted to get data, but the manuscript was under publication so the authors of this review waited till the study was published. This study was funded by Laerdal Foundation for Acute Medicine.

Pejovic 2015 *(Continued)*

LMA= Laryngeal mask airway

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation carried out by drawing a black or white toothpick from an opaque container at the time of resuscitation.
Allocation concealment (selection bias)	Low risk	Random allocation concealed until the time of initiation of resuscitation.
Blinding (performance bias and detection bias) All outcomes	High risk	No blinding attempted.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Primary outcome data available for all participants.
Selective reporting (reporting bias)	Low risk	Trial protocol available in public domain.

Singh 2005

Methods	RCT
Participants	50 infants delivered surgically. **Inclusion criteria** • Gestational age > 35 weeks. • Birth weight > 1500 g. • Apnoea > 30 seconds. • Apgar score at 1 minute < 6. • Heart rate < 100 bpm after 30 seconds. **Exclusion criteria** • Gestational age < 35 weeks. • Birth weight < 1500 g. • Thick meconium-stained amniotic fluid.
Interventions	Group I (N = 25): Resuscitated with LMA. Group II (N = 25): Resuscitated with face mask.
Outcomes	Number of attempts required for correct insertion of LMA, Time required for insertion of LMA, success of ventilation based on chest expansion and breath sounds heard bilaterally, pink up time, Apgar score at 1 and 5 minute, total duration of PPV, difficulties/complications encountered, need for endotracheal intubation, maximum inflation pressure required for adequate chest inflation.
Notes	Contacted authors and information received regarding Allocation concealment and randomisation but authors could not provide standard deviations for various outcomes. Source of funding not mentioned. A=Activity, P=pulse, G=Grimace, A=appearance, R= Respiration

Singh 2005 *(Continued)*

BW= Birth Weight

GA = Gestational age

HR = Heart rate

LMA = Laryngeal mask airway

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Identical folded slips of paper mentioning the two study interventions were placed in an opaque bottle.
Allocation concealment (selection bias)	Low risk	Clinician was unaware of allocation until the need for intervention.
Blinding (performance bias and detection bias) All outcomes	High risk	Blinding of interventions not feasible.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcomes reported on all participants entered into trial.
Selective reporting (reporting bias)	Unclear risk	No trial protocol available in public domain.

Trevisanuto 2015

Methods	A prospective, randomised, parallel 1:1, unblinded, controlled trial. To assess the effectiveness of size 1 supreme laryngeal mask airway over face mask ventilation for preventing need for endotracheal intubation at birth.
Participants	142 newborns ≥ 34 weeks' gestation or expected birth weight ≥ 1500 g needing positive pressure ventilation at birth.
Interventions	Intervention group: Resuscitation with a supreme LMA (LMA Supreme, LMA Company, UK) (N = 71) Control group: Resuscitation using a face mask (N = 71).
Outcomes	**Primary outcome** • Proportion of newborns needing endotracheal intubation. **Secondary outcomes** • Apgar score at 5 minutes. • Time to first breath. • Onset of the first cry. • Duration of resuscitation. • Death or moderate to severe hypoxic ischaemic encephalopathy within 7 days of life.
Notes	ClinicalTrials.gov: NCT01963936 (11 October 2013)

Trevisanuto 2015 *(Continued)*

Authors were not contacted during the preparation of this review. Source of funding was not mentioned.

A=Activity, P=pulse, G=Grimace, A=appearance, R= Respiration

BW= Birth Weight

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated, randomised sequence.
Allocation concealment (selection bias)	Low risk	Randomised allocation was concealed in double-enclosed, opaque, sealed, and sequentially numbered envelopes.
Blinding (performance bias and detection bias) All outcomes	High risk	Neither caregivers nor outcome assessors were masked to treatment allocation.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Primary outcome data available for all participants. Apgar score at 5 minutes not available for 6 infants (secondary outcome).
Selective reporting (reporting bias)	Low risk	Trial protocol available in public domain.

Yang 2016

Methods	Quasi-randomised study of the feasibility, efficacy and safety of using laryngeal mask (LM) ventilation compared with endotracheal intubation (ETI) during neonatal resuscitation. Single centre study; 68 infants born between June 2010 to December 2011.
Participants	**Inclusion criteria** • Gestational age ≥ 34 weeks, or • Anticipated birth weight ≥ 2 kg. • Heart rate < 60 bpm, despite BMV for 30 seconds. **Exclusion criteria** • Absent heart rate at birth and known major congenital malformations (e.g. congenital diaphragmatic hernia or cyanotic congenital heart disease).
Interventions	LMA group (N = 36). Endotracheal intubation group (N = 32).
Outcomes	Differences in first attempt insertion success, insertion time, Apgar score, resuscitation outcome, and adverse effects.
Notes	Current Controlled Trials registration: ChiCTR-IOQ-15006488 (2 June 2015) The Guangdong Province Science and Technology Program provided financial assistance for this study. Authors were not contacted during the preparation of this review.

Yang 2016 *(Continued)*

LMA= Laryngeal mask airway

ETI= Endotracheal intubation

A=Activity, P=Pulse, G=Grimace, A=Appearance, R= Respiration

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	LMA was used on even dates and the ETT on odd dates.
Allocation concealment (selection bias)	High risk	Since allocation was done by even and odd days, it could not have been concealed.
Blinding (performance bias and detection bias) All outcomes	High risk	Unblinded study.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcomes reported on all participants entered into trial.
Selective reporting (reporting bias)	Low risk	Trial protocol available in public domain.

Zhu 2011

Methods	Prospective, quasi-randomised trial. Single centre study; 369 infants born between February 2007 and February 2009
Participants	**Inclusion criteria** • Gestational age: ≥ 34 weeks. • Expected birth weight ≥ 2 kg. • Requiring positive pressure ventilation at birth (apnoea or gasping). • Heart rate < 100 bpm after initial resuscitation measures i.e. providing warmth, positioning, clearing the airway, drying and stimulation, over the first 30 seconds, or by the presence of persistent central cyanosis despite receiving supplementary oxygen). **Exclusion criteria** • Still-births • Severe prenatal depression (with Apgar score of 0 or 1 at 1 minute after birth) • Major malformations of the respiratory system Cyanotic congenital heart disease
Interventions	LMA Group: (N = 205) BMV Group: (N = 164)
Outcomes	Apgar score at 1 minute and 5 minutes after birth; LMA insertion time, the rate of successful insertion at the first attempt, and the number of attempts required to insert the LMA successfully; duration of resuscitation; response time (the time period from starting LMA resuscitation to achieving an effective response); ventilation time; adverse effects during resuscitation.

Zhu 2011 *(Continued)*

	Arterial blood gases, lactic acid and blood sugar level before and after resuscitation in 20 infants from each group.
Notes	Shenzhen Science and Technology Programme provided financial assistance for this study; Authors were not contacted during the preparation of this review. A=Activity, P=pulse, G=Grimace, A=appearance, R= Respiration BMV = Bag mask ventilation GA = Gestational age HR = Heart rate LMA = Laryngeal mask airway

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Eligible participants born on even date received LMA whereas participants born on odd dates received BMV.
Allocation concealment (selection bias)	High risk	Since allocation was done by even and odd days, it could not have been concealed.
Blinding (performance bias and detection bias) All outcomes	High risk	Unblinded study.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcomes reported on all participants entered into trial.
Selective reporting (reporting bias)	Unclear risk	No trial protocol available in public domain.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Attridge 2013	Single centre study used LMA for surfactant administration in non-resuscitation settings.
Baker 2004	Not a randomised or quasi-randomised trial. A single patient case report.
Baraka 1995	Not a randomised or quasi-randomised trial. A single patient case report.
Barbosa 2012	Study used LMA for surfactant administration in non-resuscitation settings
Barbosa 2017	Study used LMA for surfactant administration in non-resuscitation settings.
Brimacombe 1995	Not a randomised or quasi-randomised trial. A single patient case report.
Brimacombe 1999	Not a randomised or quasi-randomised trial. A single patient case report.

Study	Reason for exclusion
Brimacombe 2004	Not a randomised or quasi-randomised trial. A case report describing 2 newborns, 1 requiring resuscitation.
Bucx 2003	Not a randomised or quasi-randomised trial. A single patient case report.
Denny 1990	Not a randomised or quasi-randomised trial. A single patient case report.
Fernandez-Jur 2002	Not a randomised or quasi-randomised trial. A single patient case report.
Fraser 1999a	Not a randomised or quasi-randomised trial. A case report describing 2 neonates requiring resuscitation.
Fraser 1999b	Not a randomised or quasi-randomised trial.
Gandini 1999	Not a randomised or quasi-randomised trial. Prospective case-series without a comparison group.
Gandini 2003	Not a randomised or quasi-randomised trial. A single patient case report.
Mawer 1995	Not a randomised or quasi-randomised trial. A single patient case report.
Nagahama 1995	Not a randomised or quasi-randomised trial. A single patient case report.
Paterson 1994	Not a randomised or quasi-randomised trial. Prospective case-series without a comparison group.
Pinheiro 2016	Study used LMA for surfactant administration in non-resuscitation settings.
Roberts 2017	Study used LMA for surfactant administration in a non-resuscitation setting.
Trawöger 1999	Not a randomised or quasi-randomised trial. A single patient case report.
Trevisanuto 2004a	Not a randomised or quasi-randomised trial. Retrospective case-series with historical and concurrent, non-randomised comparison groups.
Trevisanuto 2004b	Not a randomised or quasi-randomised trial. A survey of anaesthesiologists and paediatricians.
Wanous 2017	Study used LMA for surfactant administration in non-resuscitation settings.
Yao 2004	Not a randomised or quasi-randomised trial. A single patient case report.
Zanardo 2004	Not a randomised or quasi-randomised trial.

DATA AND ANALYSES

Comparison 1. LMA versus BMV

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Failure with primary modality of resuscitation	5	660	Risk Ratio (M-H, Fixed, 95% CI)	0.16 [0.09, 0.30]

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
2 Need for intubation	5	660	Risk Ratio (IV, Fixed, 95% CI)	0.24 [0.12, 0.47]
3 Time to spontaneous breathing	2	511	Mean Difference (IV, Fixed, 95% CI)	-1.45 [-2.98, 0.08]
4 Ventilation time [seconds]	4	610	Mean Difference (IV, Fixed, 95% CI)	-18.90 [-24.35, -13.44]
5 Apgar score ≤ 7 at 5 min	2	511	Risk Ratio (M-H, Fixed, 95% CI)	0.34 [0.16, 0.74]
6 Admission to NICU	2	191	Risk Ratio (M-H, Fixed, 95% CI)	0.6 [0.40, 0.90]
7 Death or HIE	2	191	Risk Ratio (M-H, Fixed, 95% CI)	0.65 [0.17, 2.43]

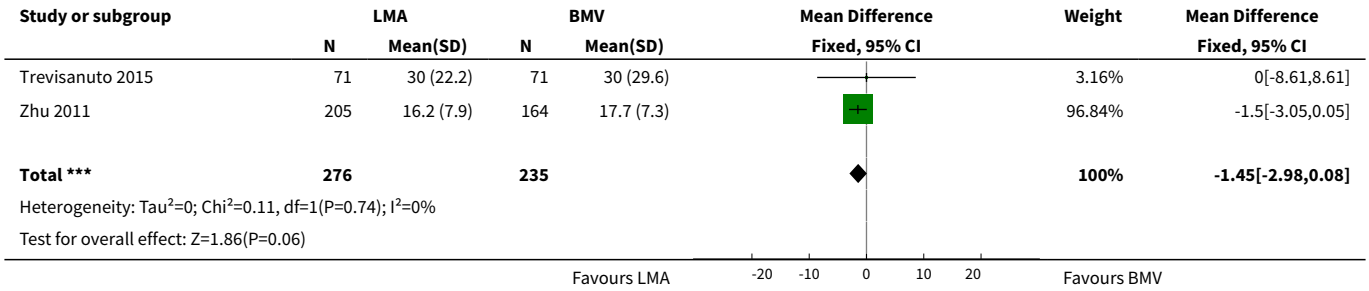
Analysis 1.1. Comparison 1 LMA versus BMV, Outcome 1 Failure with primary modality of resuscitation.

Study or subgroup	LMA n/N	BMV n/N	Risk Ratio M-H, Fixed, 95% CI	Weight	Risk Ratio M-H, Fixed, 95% CI
Feroze 2008	1/25	5/25		7.92%	0.2[0.03,1.59]
Pejovic 2015	0/24	11/25		17.85%	0.05[0,0.73]
Singh 2005	1/25	3/25		4.75%	0.33[0.04,2.99]
Trevisanuto 2015	6/71	15/71		23.75%	0.4[0.16,0.97]
Zhu 2011	2/205	26/164		45.74%	0.06[0.01,0.26]
Total (95% CI)	**350**	**310**		**100%**	**0.16[0.09,0.3]**
Total events: 10 (LMA), 60 (BMV)					
Heterogeneity: Tau^2=0; Chi^2=7, df=4(P=0.14); I^2=42.82%					
Test for overall effect: Z=5.67(P<0.0001)					

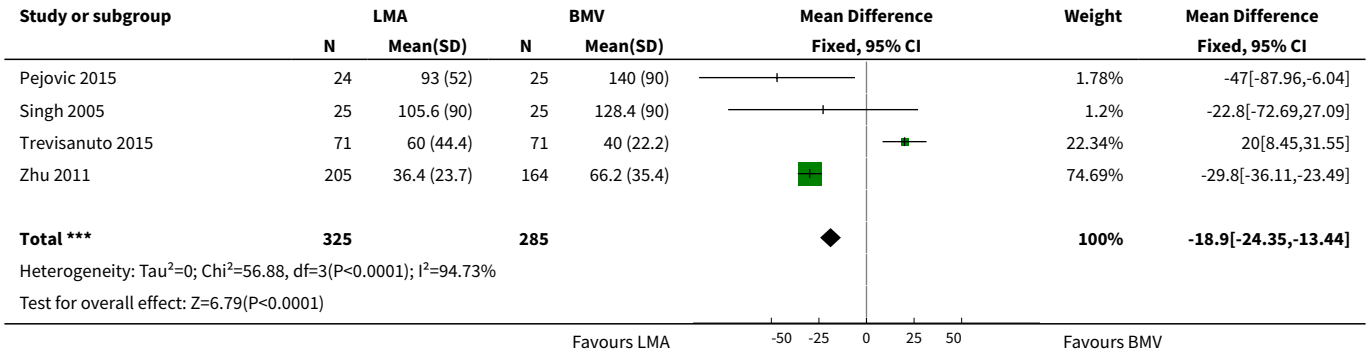
Analysis 1.2. Comparison 1 LMA versus BMV, Outcome 2 Need for intubation.

Study or subgroup	LMA n/N	BMV n/N	Risk Ratio IV, Fixed, 95% CI	Weight	Risk Ratio IV, Fixed, 95% CI
Feroze 2008	1/25	5/25		10.55%	0.2[0.03,1.59]
Pejovic 2015	0/24	0/25			Not estimable
Singh 2005	1/25	3/25		9.43%	0.33[0.04,2.99]
Trevisanuto 2015	6/71	15/71		57.61%	0.4[0.16,0.97]
Zhu 2011	2/205	26/164		22.41%	0.06[0.01,0.26]
Total (95% CI)	**350**	**310**		**100%**	**0.24[0.12,0.47]**
Total events: 10 (LMA), 49 (BMV)					
Heterogeneity: Tau^2=0; Chi^2=4.9, df=3(P=0.18); I^2=38.76%					
Test for overall effect: Z=4.15(P<0.0001)					

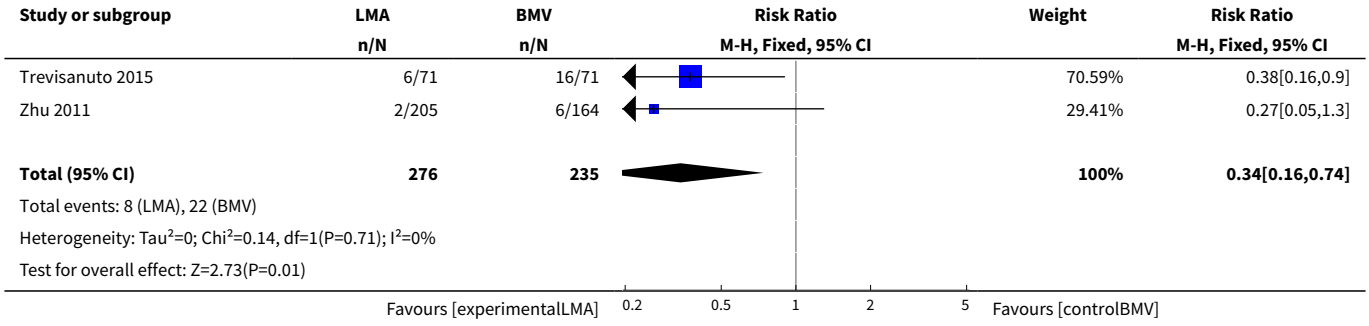
Analysis 1.3. Comparison 1 LMA versus BMV, Outcome 3 Time to spontaneous breathing.



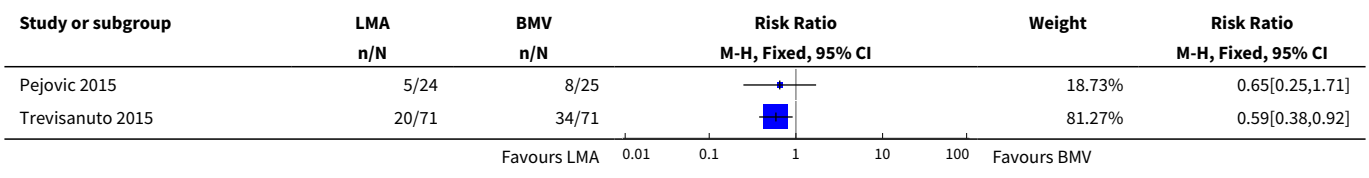
Analysis 1.4. Comparison 1 LMA versus BMV, Outcome 4 Ventilation time [seconds].

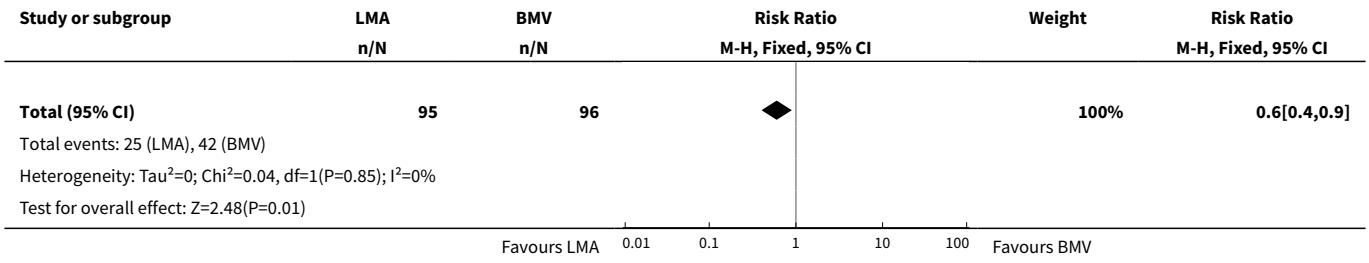


Analysis 1.5. Comparison 1 LMA versus BMV, Outcome 5 Apgar score ≤ 7 at 5 min.

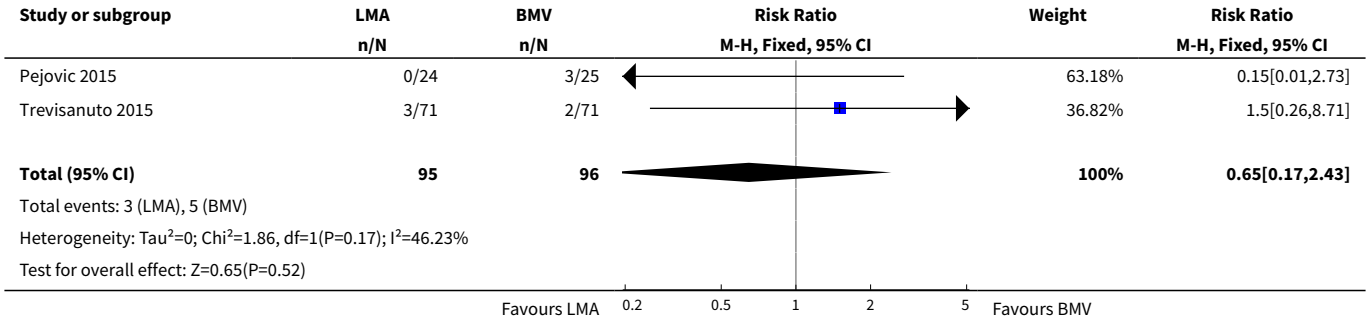


Analysis 1.6. Comparison 1 LMA versus BMV, Outcome 6 Admission to NICU.





Analysis 1.7. Comparison 1 LMA versus BMV, Outcome 7 Death or HIE.

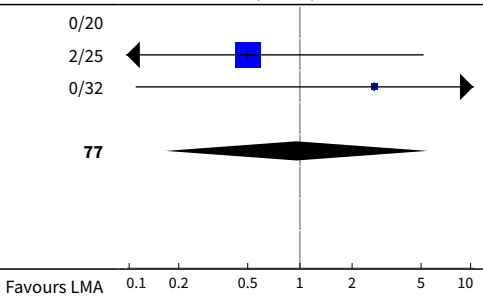


Comparison 2. LMA versus endotracheal intubation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Failure to correctly insert the device	3	158	Risk Ratio (M-H, Fixed, 95% CI)	0.95 [0.17, 5.42]
2 Successful insertion of device at first attempt	2	108	Risk Ratio (M-H, Fixed, 95% CI)	1.01 [0.89, 1.14]
3 Insertion time	2	108	Mean Difference (IV, Fixed, 95% CI)	0.31 [-0.27, 0.88]
4 Ventilation time [seconds]	1	68	Mean Difference (IV, Fixed, 95% CI)	-33.90 [-73.11, 5.31]
5 Apgar score ≤7 at 5 minutes	2	108	Risk Ratio (M-H, Fixed, 95% CI)	0.70 [0.34, 1.45]
6 Soft tissue trauma after device inserted	1	40	Risk Ratio (M-H, Fixed, 95% CI)	2.0 [0.58, 6.91]
7 Death or HIE	1	68	Risk Ratio (M-H, Fixed, 95% CI)	0.59 [0.11, 3.32]

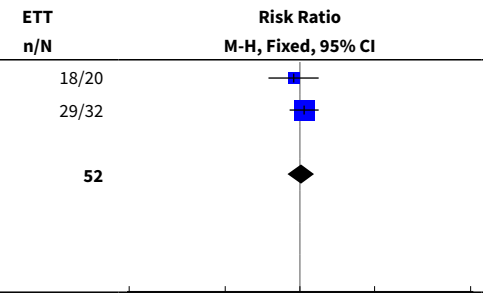
Analysis 2.1. Comparison 2 LMA versus endotracheal intubation, Outcome 1 Failure to correctly insert the device.

Study or subgroup	LMA n/N	ETT n/N	Risk Ratio M-H, Fixed, 95% CI	Weight	Risk Ratio M-H, Fixed, 95% CI
Esmail 2002	0/20	0/20			Not estimable
Feroze 2008	1/25	2/25		79.1%	0.5[0.05,5.17]
Yang 2016	1/36	0/32		20.9%	2.68[0.11,63.45]
Total (95% CI)	**81**	**77**		**100%**	**0.95[0.17,5.42]**
Total events: 2 (LMA), 2 (ETT)					
Heterogeneity: Tau^2=0; Chi^2=0.7, df=1(P=0.4); I^2=0%					
Test for overall effect: Z=0.05(P=0.96)					



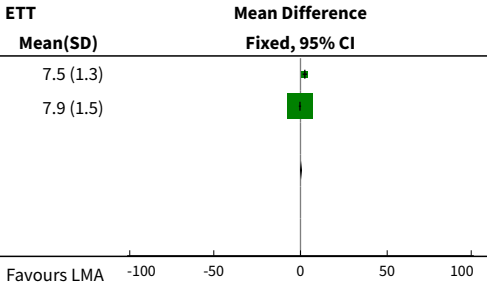
Analysis 2.2. Comparison 2 LMA versus endotracheal intubation, Outcome 2 Successful insertion of device at first attempt.

Study or subgroup	LMA n/N	ETT n/N	Risk Ratio M-H, Fixed, 95% CI	Weight	Risk Ratio M-H, Fixed, 95% CI
Esmail 2002	17/20	18/20		36.96%	0.94[0.75,1.19]
Yang 2016	34/36	29/32		63.04%	1.04[0.91,1.19]
Total (95% CI)	**56**	**52**		**100%**	**1.01[0.89,1.14]**
Total events: 51 (LMA), 47 (ETT)					
Heterogeneity: Tau^2=0; Chi^2=0.53, df=1(P=0.47); I^2=0%					
Test for overall effect: Z=0.1(P=0.92)					



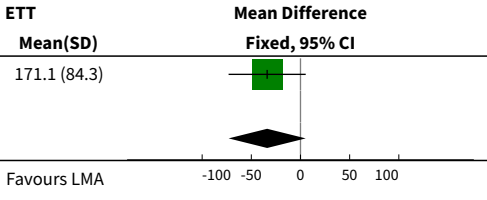
Analysis 2.3. Comparison 2 LMA versus endotracheal intubation, Outcome 3 Insertion time.

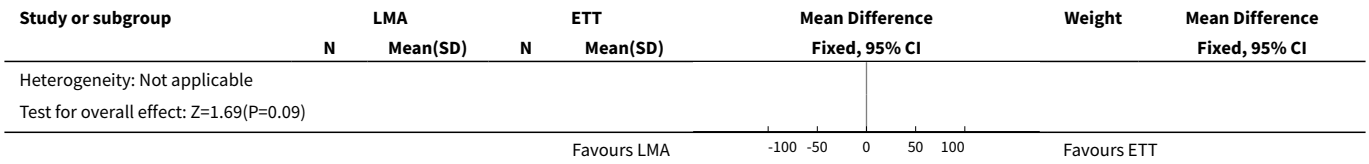
Study or subgroup	LMA N	LMA Mean(SD)	ETT N	ETT Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Esmail 2002	20	10 (2.5)	20	7.5 (1.3)		21.74%	2.5[1.27,3.73]
Yang 2016	36	7.6 (1.2)	32	7.9 (1.5)		78.26%	-0.3[-0.95,0.35]
Total ***	**56**		**52**			**100%**	**0.31[-0.27,0.88]**
Heterogeneity: Tau^2=0; Chi^2=15.45, df=1(P<0.0001); I^2=93.53%							
Test for overall effect: Z=1.05(P=0.29)							



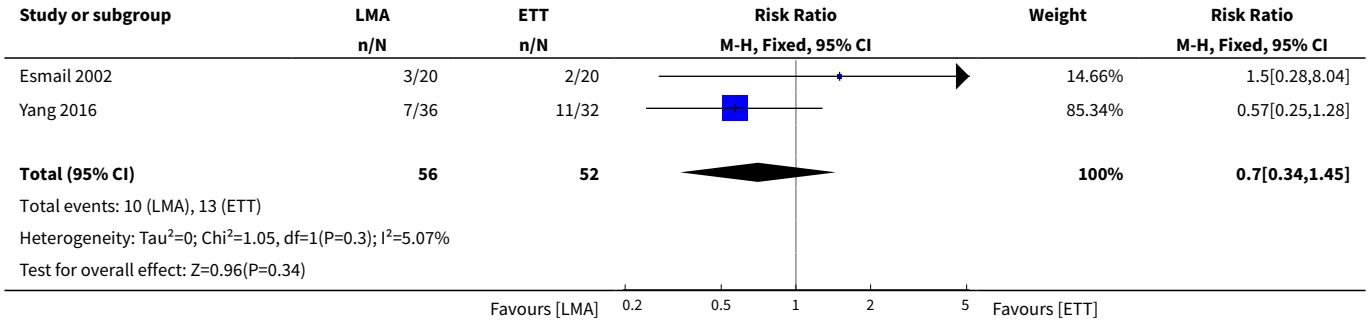
Analysis 2.4. Comparison 2 LMA versus endotracheal intubation, Outcome 4 Ventilation time [seconds].

Study or subgroup	LMA N	LMA Mean(SD)	ETT N	ETT Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Yang 2016	36	137.2 (80.1)	32	171.1 (84.3)		100%	-33.9[-73.11,5.31]
Total ***	**36**		**32**			**100%**	**-33.9[-73.11,5.31]**

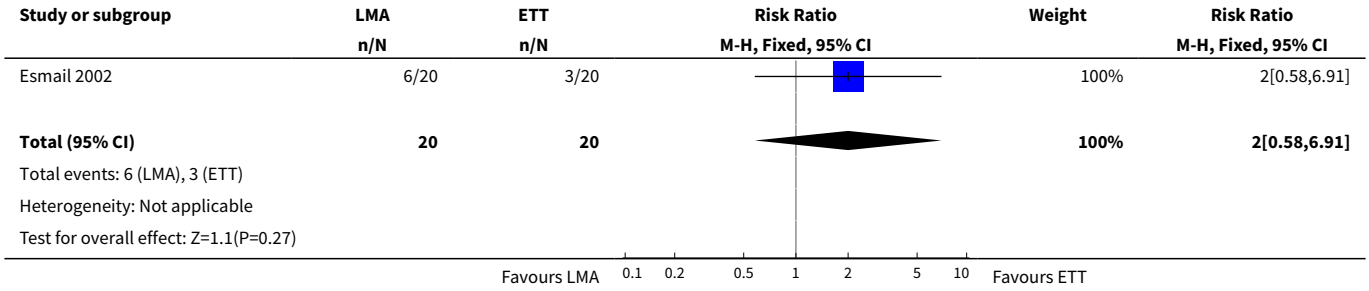




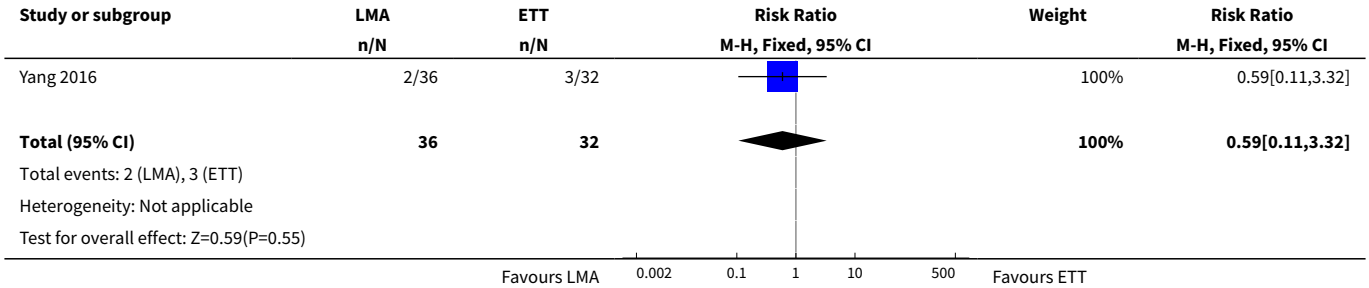
Analysis 2.5. Comparison 2 LMA versus endotracheal intubation, Outcome 5 Apgar score ≤7 at 5 minutes.



Analysis 2.6. Comparison 2 LMA versus endotracheal intubation, Outcome 6 Soft tissue trauma after device inserted.



Analysis 2.7. Comparison 2 LMA versus endotracheal intubation, Outcome 7 Death or HIE.



APPENDICES

Appendix 1. Cochrane Neonatal standard search strategy

PubMed: ((infant, newborn[MeSH] OR newborn OR neonate OR neonatal OR premature OR low birth weight OR VLBW OR LBW or infan* or neonat*) AND (randomized controlled trial [pt] OR controlled clinical trial [pt] OR randomized [tiab] OR placebo [tiab] OR drug therapy [sh] OR randomly [tiab] OR trial [tiab] OR groups [tiab]) NOT (animals [mh] NOT humans [mh]))

Embase: (infant, newborn or newborn or neonate or neonatal or premature or very low birth weight or low birth weight or VLBW or LBW or Newborn or infan* or neonat*) AND (human not animal) AND (randomized controlled trial or controlled clinical trial or randomized or placebo or clinical trials as topic or randomly or trial or clinical trial)

CINAHL: (infant, newborn OR newborn OR neonate OR neonatal OR premature OR low birth weight OR VLBW OR LBW or Newborn or infan* or neonat*) AND (randomized controlled trial OR controlled clinical trial OR randomized OR placebo OR clinical trials as topic OR randomly OR trial OR PT clinical trial)

Cochrane Library: (infant or newborn or neonate or neonatal or premature or preterm or very low birth weight or low birth weight or VLBW or LBW)

Appendix 2. Risk of bias tool

1. Sequence generation (checking for possible selection bias). Was the allocation sequence adequately generated?

For each included study, we categorized the method used to generate the allocation sequence as:

- low risk (any truly random process e.g. random number table; computer random number generator);
- high risk (any non-random process e.g. odd or even date of birth; hospital or clinic record number); or
- unclear risk.

2. Allocation concealment (checking for possible selection bias). Was allocation adequately concealed?

For each included study, we categorized the method used to conceal the allocation sequence as:

- low risk (e.g. telephone or central randomization; consecutively numbered sealed opaque envelopes);
- high risk (open random allocation; unsealed or non-opaque envelopes, alternation; date of birth); or
- unclear risk

3. Blinding of participants and personnel (checking for possible performance bias). Was knowledge of the allocated intervention adequately prevented during the study?

For each included study, we categorized the methods used to blind study participants and personnel from knowledge of which intervention a participant received. Blinding was assessed separately for different outcomes or class of outcomes. We categorized the methods as:

- low risk, high risk or unclear risk for participants; and
- low risk, high risk or unclear risk for personnel.

4. Blinding of outcome assessment (checking for possible detection bias). Was knowledge of the allocated intervention adequately prevented at the time of outcome assessment?

For each included study, we categorized the methods used to blind outcome assessment. Blinding was assessed separately for different outcomes or class of outcomes. We categorized the methods as:

- low risk for outcome assessors;
- high risk for outcome assessors; or
- unclear risk for outcome assessors.

5. Incomplete outcome data (checking for possible attrition bias through withdrawals, dropouts, protocol deviations). Were incomplete outcome data adequately addressed?

For each included study and for each outcome, we described the completeness of data including attrition and exclusions from the analysis. We noted whether attrition and exclusions were reported, the numbers included in the analysis at each stage (compared with the total randomized participants), reasons for attrition or exclusion where reported, and whether missing data were balanced across groups or were related to outcomes. Where sufficient information was reported or supplied by the trial authors, we re-included missing data in the analyses. We categorized the methods as:

- low risk (< 20% missing data);
- high risk (≥ 20% missing data); or
- unclear risk.

6. Selective reporting bias. Are reports of the study free of suggestion of selective outcome reporting?

For each included study, we described how we investigated the possibility of selective outcome reporting bias and what we found. For studies in which study protocols were published in advance, we compared prespecified outcomes versus outcomes eventually reported in the published results. If the study protocol was not published in advance, we contacted study authors to gain access to the study protocol. We assessed the methods as:

- low risk (where it is clear that all of the study's prespecified outcomes and all expected outcomes of interest to the review have been reported);
- high risk (where not all the study's prespecified outcomes have been reported; one or more reported primary outcomes were not prespecified outcomes of interest and are reported incompletely and so cannot be used; study fails to include results of a key outcome that would have been expected to have been reported); or
- unclear risk.

7. Other sources of bias. Was the study apparently free of other problems that could put it at a high risk of bias?

For each included study, we described any important concerns we had about other possible sources of bias (for example, whether there was a potential source of bias related to the specific study design or whether the trial was stopped early due to some data-dependent process). We assessed whether each study was free of other problems that could put it at risk of bias as:

- low risk;
- high risk;
- unclear risk

If needed, we explored the impact of the level of bias through undertaking sensitivity analyses.

WHAT'S NEW

Date	Event	Description
27 October 2017	New citation required and conclusions have changed	Six new trials were located in the search done in February 2017, and changes were made in the review and its conclusions.
27 October 2017	New search has been performed	This updates the review, "Laryngeal mask airway versus bag-mask ventilation or endotracheal intubation for neonatal resuscitation" (Grein 2005).

HISTORY

Protocol first published: Issue 4, 2001
Review first published: Issue 2, 2005

Date	Event	Description
10 November 2008	Amended	Converted to new review format.

CONTRIBUTIONS OF AUTHORS

Both authors (MQ and MK) searched literature, reviewed studies, co-authored text, entered data and checked data entry for accuracy.

DECLARATIONS OF INTEREST

None

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

We made changes to outcomes presented in the previous version of this review after extensive discussion among review authors with the aim of making the review more meaningful in terms of clinical practice.

Additional searches:

We have added another search engine (EMBASE) to ensure wider coverage of the evidence.

Primary outcomes:

Our search identified studies comparing LMA to BMV, which were not available at the time of the previous version of this review. Also the newly identified studies reported additional outcomes. As such we amended the primary outcomes according to clinical significance. We included:

1. Need for endotracheal intubation (LMA vs. BMV studies only).
2. Failure with primary modality of resuscitation (LMA vs. BMV studies only)
3. Ventilation time (Time from birth, or from the beginning of intervention, until the discontinuation of positive pressure ventilation as part of resuscitation).
4. Time to spontaneous breathing (or described as time to definitive response following the onset of intervention).
5. Admission to NICU
6. Death or hypoxic Ischemic encephalopathy (HIE) in the delivery room.

Secondary outcomes:

After discussion, we amended secondary outcomes in this review to include the following:

1. Time until heart rate greater than 100 beats/minute.
2. Apgar score less than or equal to 7 at 5 minutes
3. Apgar scores at 5 and 10 minutes
4. Frequency of post-resuscitation oral, airway, or facial trauma, or any other procedural related complication

INDEX TERMS

Medical Subject Headings (MeSH)

*Masks; Hypoxia, Brain [etiology]; Intensive Care Units, Neonatal [statistics & numerical data]; Intubation, Intratracheal [instrumentation] [methods]; Laryngeal Masks; Positive-Pressure Respiration [instrumentation] [*methods]; Randomized Controlled Trials as Topic; Resuscitation [instrumentation] [*methods]

MeSH check words

Humans; Infant, Newborn